Linear parameter-varying control of an industrial AGV using a novel practical design interface

Laurens Jacobs, Gijs Hilhorst, Jan Swevers and Goele Pipeleers
KU Leuven, BE-3001 Heverlee, Belgium
Department of Mechanical Engineering, Division PMA
laurens.jacobs@kuleuven.be

1 Introduction

Optimal feedback controller design methods based on $\mathscr{H}_\infty$ criteria have been widely studied throughout the past decades. Although these modern approaches have shown promising results in academic contexts, it appears that classical open-loop shaping techniques are still dominating in many industrial environments. In particular, the limited affinity with the advanced mathematical tools needed for optimal controller synthesis is an important obstacle for control engineers in industry. Some efforts have already been made to develop a high-level design interface to overcome this issue [1].

This existing MATLAB interface is currently being extended for multivariable linear parameter-varying (LPV) systems, relying on B-spline based LMI relaxations [2]. The following paragraphs discuss the application of this novel design interface on a practical industrial case: position control of an automated guided vehicle (AGV).

2 Formulation and control strategy

The motion of the AGV in a world frame XY, shown in Figure 1, is described by a well-known nonlinear kinematic bicycle model (Equation (1)).

$$\begin{cases} \dot{x} = V\cos\theta \\ \dot{y} = V\sin\theta \\ \dot{\theta} = \frac{V}{L}\tan\delta \end{cases} \quad (1) \qquad \begin{cases} \dot{x}' = V + y'\dot{\theta}_\mathrm{r} \\ \dot{y}' = V(\theta' - \theta_\mathrm{r}) - x'\dot{\theta}_\mathrm{r} \\ \dot{\theta}' = \frac{V}{L}\tan\delta \end{cases} \quad (2)$$

V represents the forward velocity, δ the steering angle and L the wheel base. Instead of directly considering the motion of the cart in the world frame XY, a local coordinate frame $X'Y'$ can be attached to the reference trajectory (Figure 1). Assuming small angles, elaboration of the kinematic equations in this frame then yields Equation (2). It represents an LPV system with control inputs $[V,\ \tan\delta]$ and scheduling parameters $[V,\ \dot{\theta}_\mathrm{r}]$. The small angle approximation holds as long as the tracking errors are not too large. Indeed, the control objective for reference tracking corresponds to maintaining the states x', y' and θ' as close to zero as possible. Figure 2 shows the control configuration we introduce for this purpose.

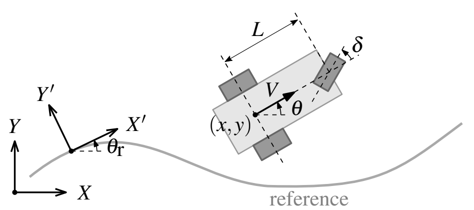

Figure 1: AGV motion in a global frame XY and in a local frame $X'Y'$ attached to the reference trajectory

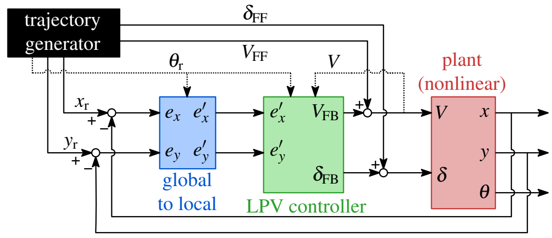

Figure 2: Overall control configuration scheme

3 Optimal controller design

The interface presented in [1] allows imposing the control performance specifications by means of convenient weighting functions for the relevant closed loop characteristics of the system. Accordingly, the scheduling parameters are intuitively defined, such that the extension from linear time-invariant (LTI) systems to LPV systems is an accessible transition for end users.

The controller resulting from this case will be tested in depth through simulations and will be validated experimentally on an industrial AGV. Parametric uncertainty (wheel base L) and unmodeled dynamics (actuator limitations, time delays) are known to have a negative impact on the control performance, if not even setting the reachable performance limit in practice. A formal yet appealing way to incorporate robustness requirements in the design interface is therefore anticipated as well.

References

[1] M. Verbandt, J. Swevers and G. Pipeleers. “An LTI control toolbox - simplifying optimal feedback controller design.” European Control Conference (ECC) 2016, June 2016, Aalborg, Denmark.

[2] G. Hilhorst, E. Lambrechts and G. Pipeleers. “Control of Linear Parameter-Varying Systems using B-Splines”. 55th IEEE Conference on Decision and Control (CDC), December 2016, Las Vegas, USA.

Acknowledgement This research is partially supported by Flanders Make: SBO ROCSIS: Robust and Optimal Control of Systems of Interacting Subsystems. The MECO Research Team is an associated research lab of Flanders Make. This work also benefits from KU Leuven-BOF PFV/10/002 Center-of-Excellence Optimization in Engineering (OPTEC) and the Belgian Programme on Interuniversity Attraction Poles, initiated by the Belgian Federal Science Policy Office (DYSCO).